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Utilization of Vermicompost on Black Raspberry Preharvest Vegetative Growth, Plant Elemental Composition and Soil Analysis Results - 1999 & 2001

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Utilization of Vermicompost on Black Raspberry – Preharvest Vegetative Growth, Plant Tissue Elemental Composition, and Soil Analysis Results – 1999 & 2000

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INTRODUCTION

Vermicomposting is a process of breaking down organic wastes in the digestive tract of earthworms (*Eisenia foetida*). Earthworms can feed upon different types of waste and create many different kinds of vermicompost. They are capable of consuming twice their weight of organic wastes per day and large amounts of earthworms can convert materials economically. The earthworm casts can be marketed with little additional processing (Eastman et al., 2001). The final product is generally an odorless peat-like material with good moisture holding capacity, nutrient content, and an active microbial population.

Some Ohio soils are low in pH, organic matter, and minor elements. Lime, granular fertilizers, and green or animal manures are suggested as soil amendments prior to planting berry crops. Soil preparation utilizing composts can be very important to a long-term perennial fruit crop such as berries (Funt and Bierman, 2000).

The black raspberry is a high quality and unique type of berry. It requires excellent internal drainage, soil with high organic matter, and balanced soil fertility (Funt et al., 2000). Research is needed to provide recommendations that can increase yields both effectively and economically. The research reported on here compares several types and rates of organic amendments, along with comparing a single pre-plant, incorporated application with plots that also receive annual surface applications. When completed, this research should help develop recommendations to make the most efficient use of vermicomposts, composts, and other organic soil amendments in small fruit production.

OBJECTIVES

1. To determine the amount and frequency to apply vermicompost or compost to black raspberry.
2. To compare plant growth to inorganic chemical fertilizer, commercial compost and food waste vermicompost.

METHODS

Tissue cultured black raspberry (*Rubus occidentalis* L.) plants, cultivar 'Jewel', were hand planted on raised beds on June 25, 1999, at the Piketon Research & Center, Piketon, Ohio. The soil is a Doles silt loam and the planting site was in sod for several years prior to moldboard plowing in the spring to prepare for raspberry planting. Lime and fertilizer were broadcast before bed preparation and planting (3 tons lime, 100 lb. P_2O_5, and 150 lb. K_2O per acre). Nitrogen (30 lb./acre) and organic amendments (vermicomposts or compost) were incorporated directly into the beds to a depth of four inches during their construction. Nitrogen in the second year was fertigated in split applications at a total rate of 40-lb. N/acre. Rows were spaced at 10 ft., beds were 6-in. high and 36-in. wide, and plants were set 24-in. apart in the row. Plots were 24 ft. long with 12 plants per plot.

Treatments compared two types of vermicompost, applied at three different rates, to an inorganic fertilizer control and a conventional compost (thermophilic or high temperature traditional composting) applied at a single rate. All plots, including those receiving organic amendments, were supplemented with the recommended rate of inorganic fertilizer. The vermicomposts used in year one were food waste

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vermicompost (FWVC) from Oregon Soil Corporation, Portland, OR and paper waste vermicompost (PWVC) from American Resource Recovery, Stockton, CA. The conventional compost (CT) was composted biosolids (sewage sludge) from Com-Til, Columbus, OH. Chemical analyses of the plant nutrient content (plus sodium) of the vermicomposts and composts used in both year one and year two are presented in Table 1. Content of selected heavy metals and other non-nutrient elements are shown in Table 6. The specific treatments (all rates given on both a wet weight and dry weight basis) were:

1. Inorganic Fertilizer Control (no organic amendment)
2. CT (1X) – 2 lb. per ft. of row: 9 T/A (wet wt.), 4.7 T/A (dry wt.)
3. FWVC (1X) – 2 lb. per ft. of row or 9 T/A (wet wt.), 5.1 T/A (dry wt.)
4. FWVC (½ X) – 1 lb. per ft. of row or 4.5 T/A (wet wt.), 2.5 T/A (dry wt.)
5. FWVC (¼ X) – ½ lb. per ft. of row 2.25 T/A (wet wt.), 1.3 T/A (dry wt.)
6. PWVC (1X) – 2 lb. per ft. of row: 9 T/A (wet wt.), 7.4 T/A (dry wt.)
7. PWVC (½ X) – 1 lb. per ft. of row: 4.5 T/A (wet wt.), 3.7 T/A (dry wt.)
8. PWVC (¼ X) – ½ lb. per ft. of row: 2.25 T/A (wet wt.), 1.8 T/A (dry wt.)

Floricanes were pruned to the ground in March 2000, to permit better plant establishment and uniformity following the late planting of 1999, so the first fruit harvest occurred in 2001. Each treatment was replicated four times in a randomized complete block design with an outside field border. All data from each plot were subjected to analysis of variance using the SAS statistical package (SAS, 1990) and procedures (i.e. PROC ANOVA). Treatment means were compared using the LSD statistic ($P<0.05$).

In 1999, soil samples were taken at the 0- to 6-in. and 6- to 12-in. depths in each plot. In 2000, plant (cane) tissue samples were collected during winter pruning (when all canes were cut to the ground). Both soil and plant samples were sent to the STAR Laboratory at OARDC for elemental analysis. Pruning dry weights were measured as an indicator of differences in plant vigor between treatments. In subsequent years, comparing dry weights of the canes removed when plants are thinned during winter pruning will provide similar measures of vegetative growth.

Each vermicompost/compost plot was split into two 12-ft. sub-plots after the first year (in late spring of 2000), with six plants per sub-plot. The inner four plants of each subplot will be used for data collection with a buffer plant on each end. One sub-plot of each treatment received only the initial planting-year vermicompost/compost application, while beginning in year two the other subplot began receiving annual surface applications of an organic amendment. These annual surface applications are being applied at lower rates than the initial incorporated applications (see below). They are also being applied on an equivalent dry weight basis, rather than an equivalent wet weight basis, to permit more accurate comparisons. The food waste vermicompost (FWVC) used in year one was not available at the time the first surface applications were made in the spring of year two, so yard waste compost (CYW) (Kurtz Bros., Columbus OH) was substituted in its place. The experimental design used in future analyses, for all data collected after plots were split into sub-plots with or without surface applications of vermicompost or compost, will be a split-plot design. For this design, the inorganic fertilizer control treatment cannot be statistically analyzed and will only be used for qualitative comparisons.

Types and rates of organic amendments (see Tables 1 and 6 for amendment composition) used as surface application treatments in the spring of year two were:

1. Inorganic Fertilizer Control (no organic amendment)
2. CT (1X) – 2.5 T/A (dry wt.)

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3. CYW (1X) – 2.5 T/A (dry wt.)
4. CYW (½ X) – 1.25 T/A (dry wt.)
5. CYW (¼ X) – 0.625 T/A (dry wt.)
6. PWVC (1X) – 2.5 T/A (dry wt.)
7. PWVC (½ X) – 1.25 T/A (dry wt.)
8. PWVC (¼ X) – 0.625 T/A (dry wt.)

All data reported on here were collected during the initial growing season of 1999 and the dormant season in the winter of 2000. Therefore, they reflect treatment differences due only to the initial, incorporated organic amendments that were applied before planting in 1999. Treatment effects from annual surface applications, including vegetative growth measurements from the winter of 2001, will be reported in next year's summary of research.

RESULTS AND DISCUSSION

Plant

Variability between replications for cane dry weight was very high, so even the large differences in vegetative growth between some of the treatments was not statistically significant (Table 2). There were some trends in this first year of data collection, however, for cane weights as well as other parameters, that should be noted and may indicate future patterns. All treatments, except the highest rate of each type of vermicompost, had more vegetative growth than the inorganic fertilizer Control. CT (1X) and FWVC (¼ X) had over 50% greater cane dry weight than the Control. For both types of vermicompost, however, cane weights decreased consistently with increasing rates of vermicompost, with the high rate only 50 to 60% of the low rate.

The large variability in cane dry weights may have been due to the late transplanting date and inherent differences between transplants than the experimental treatments. Planting in early summer rather than in the spring exposed the transplants to hotter, drier weather and overall greater stress during establishment. Transplants always vary somewhat in size, root mass, and general vigor, but in good growing conditions the weaker transplants often catch up with the stronger ones, whereas stressful conditions can magnify any early differences in vigor.

Differences in cane elemental content (Table 2) generally reflected differences in the elemental content of the organic amendments and their application rates (Table 1), although application did not always translate into additional uptake. CT (1X) had the highest phosphorus (P), potassium (K), manganese (Mn), molybdenum (Mo), and zinc (Zn) concentration. It was significantly higher than the Control and some vermicompost treatments in P, Mn, and Zn, and tended to be higher in N, but had the lowest copper (Cu) concentration of any treatment. FWVC (½ X), PWVC (1X), PWVC (½ X) had the highest N concentrations and were all significantly greater than the Control. FWVC (½ X) was also significantly greater than the Control in P. PWVC (1X) had the highest B and Na concentrations.

Soil

Soil pH in the 0- to 6-in. depth was lower in all organically amended treatments, except the lowest FWVC rate (¼ X), than in the inorganic fertilizer Control (Table 3). Biosolids compost was the only treatment that was statistically lower than the Control, and CT (1X) and PWVC (½ X) were both significantly lower than FWVC (¼ X). Although PWVC treatments tended to reduce pH more than FWVC, this was probably due to the higher dry wt. application rates (Table 1). In other studies, composted municipal

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sludge also tended to reduce soil pH at the 0- to 6-in. depth (Funt and Hummel, 1996).

CT (1X) was significantly greater in available soil P than any other treatment (Table 3). The highest rate of FWVC (1X) and all rates of PWVC also tended to increase soil P above the Control. All organic amendment rates increased soil K, Ca, NO_3-N, and organic matter above the Control, but the only significant increases were for FWVC (1X) and PWVC (¼ X) in available K and PWVC (½ X) in organic matter. Available Mg was similar for all treatments in the 0- to 6-in. soil depth, but all types and rates of organic amendment increased total soil N and the increases for all except FWVC (1X) and FWVC (¼ X) were significant.

Soil pH, available P, K, Ca, and Mg, and organic matter in the 6- to 12-in. soil depth were not affected by treatment (Table 4), except for significantly higher P for PWVC (½ X) than FWVC (½ X). All organic amendments increased soil NO_3-N above the Control, but variability was high and none of these differences were significant. All types and rates of organic amendment, except FWVC (1X), also increased total soil N above the Control in the 6- to 12-in. depth, and the increases for all PWVC rates were significant.

Concentrations of total extractable elements in the zone of vermicompost incorporation (0- to 6-in. soil depth, Table 5) are of interest for the possible adverse effects of heavy metals and other elements in organic amendments on plant growth or the environment, as well as their potentially positive effects on essential plant nutrients. All amendments increased total soil B, Mo, and S, all but FWVC (¼ X) increased Cu, and all except FWVC (½ X) increased P and Zn. Compared to the Control, there were statistically significant increases in B, Cu, K, and Mg from PWVC (½ X), in Cu, P, and Zn from CT (1X), and in S from FWVC (½ X). All of these elements are essential plant nutrients, but B and Mo can also be phytotoxic at relatively low concentrations and Cu and Zn can be environmental concerns at high concentrations. The increases shown in Table 5 are not high enough to indicate potential problems at the amendment rates used in this study (Ohio EPA, 1998) and cane elemental concentrations (Table 2) indicate little risk of plant toxicity (Mills and Jones, 1996).

Table 6 shows the content of potentially problematic non-nutrient chemical elements in the various organic amendments used in this research. Biosolids are a government-regulated soil amendment, because of their historically high content in industrial locations of heavy metals and other elements that pose environmental risks. It is interesting to note that cadmium is the only element in Table 6 that is present at the highest concentration in the biosolids compost. It is actually the lowest of all organic sources in both chromium and strontium, lower than paper waste vermicompost in cobalt, nickel, and selenium, and lower than food waste vermicompost in lead. If the waste stream is clean, biosolids compost is as safe for agricultural uses as seemingly more benign organic materials. At the rates applied, none of these organic amendments are hazardous to human health or the environment (Ohio EPA, 1998).

Statistics

Individual treatment means for these data were compared using the LSD method of mean separation. The nature of the treatments used in this experiment requires that these and future data be analyzed using a method such as orthogonal contrasts that permits grouping of treatment categories (e.g. comparing all food waste vermicompost treatments with all paper waste vermicompost treatments or looking at trends associated with increasing rates of a single type of vermicompost). This type of analysis will allow better conclusions, interpretations, and recommendations to be drawn from the results.

CONCLUSIONS

This experiment is in the initial stages of testing different amounts and types of vermicompost versus a conventional, high-temperature compost (from biosolids) and a standard, inorganic fertilizer treatment

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without addition of any organic amendment. The first harvest of berries will occur in 2001, but measurement of differences in early vegetative growth, plant elemental composition, and soil elemental content was made in 1999-2000. Raspberry cane weight was not statistically affected by treatment, but except for the highest vermicompost rates, use of organic amendments increased vegetative growth above the inorganic fertilizer Control. Biosolids compost and the lowest rate (1.3 T/A dry wt.) of food waste vermicompost increased cane weight by 56%. Biosolids compost and vermicomposts both affected plant and soil elemental content. Organic amendments generally increased cane N, P, B, and Mo, although only some of the differences were statistically significant. Compost and vermicomposts tended to reduce soil pH, but do increase organic matter, S, both organic and inorganic N, available P, K, and Ca, and the micronutrients B, Mo, Cu, and Zn. Results in the next few years after fruit harvest begins will give a more complete picture of the value of vermicompost amendments. Their practical use requires that they be more than a nutrient source, and increase growth and yield through additional effects on other soil properties like microbial activity, water relations, and disease suppression.

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Table 1. Chemical Composition of Vermicomposts and Compost Applied to Black Raspberries, Piketon 1999-2000.														
Amendment Type	**Dry Wt.**	**N**	**B**	**Ca**	**Cu**	**Fe**	**K**	**Mg**	**Mn**	**Mo**	**Na**	**P**	**S**	**Zn**
	------- % -------		---ppm---											
Food Waste Vermicompost	57.1	1.30	23.3	18,600	45.6	23,250	9200	4360	610	<0.6	842	2750	2590	279
Paper Waste Vermicompost	81.8	1.00	31.4	9,200	45.3	17,800	6250	7660	447	1.3	613	1400	1930	127
Biosolids Compost	52.6	2.60	33.2	27,950	199.0	7,700	6450	7190	364	9.0	930	18,350	6290	1280
Yard Waste Compost [z]	73.7	1.18	45.2	74,800	14.9	3,950	5720	20,100	264	<0.6	<5.0	1300	2430	66

[z] Replaced Food Waste Vermicompost for the spring, 2000 surface application

Table 2. Vermicompost Raspberries Cane Pruning Weights and Elemental Analysis, Piketon 2000.														
Treatment[z]	**Cane Dry Weight**	**P**	**K**	**Ca**	**Mg**	**Al**	**B**	**Cu**	**Fe**	**Mn**	**Mo**	**Na**	**Zn**	**Cane Nitrogen**
	grams	---ppm---												%
Inorganic Fertilizer Control	225 a	1300 b	3810 ab	4860	1740	136	15.5 b	5.13 ab	105	117 ab	0.53 b	47.3 ab	39.1 b	1.71 c
Biosolids Compost – 1X	353 a	1430 a	4100 a	4700	1770	137	15.8 ab	4.43 b	108	144 a	0.83 a	56.6 ab	55.6 a	1.86 abc
Food Waste Vermicompost – 1X	171 a	1290 b	3640 ab	5160	1770	195	16.3 ab	5.00 ab	140	105 ab	0.75 ab	45.7 ab	43.3 b	1.75 abc
Food Waste Vermicompost – ½ X	315 a	1420 a	3670 ab	4670	1810	186	16.6 ab	5.03 ab	134	104 ab	0.60 ab	38.0 b	38.0 b	1.93 a
Food Waste Vermicompost – ¼ X	351 a	1350 ab	3800 ab	5080	1820	141	16.3 ab	5.05 ab	111	84 b	0.63 ab	44.4 ab	37.1 b	1.73 bc
Paper Waste Vermicompost – 1 X	185 a	1360 ab	3940 ab	5350	1860	198	17.2 a	5.15 ab	136	123 ab	0.70 ab	85.5 a	43.3 b	1.91 ab
Paper Waste Vermicompost – ½ X	285 a	1370 ab	3350 b	4500	1790	220	15.9 ab	4.93 ab	149	90 b	0.63 ab	37.3 b	38.8 b	1.91 ab
Paper Waste Vermicompost – ¼ X	316 a	1340 ab	3890 ab	4940	1740	151	16.1 ab	5.53 a	114	108 ab	0.53 b	47.3ab	37.4 b	1.74 bc
LSD (0.05)	292	90	680	1210	215	140	1.7	0.88	64	46	0.27	43.4	9.77	0.19

[z] Means followed by the same letter are not significantly different at the 0.05 level, LSD

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Table 3. Vermicompost Raspberries Soil Analysis: pH, Available Nutrients, Organic Matter, and Total Soil Nitrogen, 0-6 inches, Piketon 1999.

Treatment[z]	pH	Bray P	Exch. K	Exch. Ca	Exch. Mg	NO_3-N	Organic Matter	Total Nitrogen
		---ppm---					%	%
Inorganic Fertilizer Control	6.35 ab	25.5 b	137 b	783	245	16.4	2.76 b	0.15 c
Biosolids Compost – 1X	6.05 b	68.5 a	161 ab	797	245	25.7	2.99 ab	0.18 a
Food Waste Vermicompost – 1X	6.20 ab	35.5 b	176 a	828	244	17.3	2.90 ab	0.165 abc
Food Waste Vermicompost – ½ X	6.30 ab	25.8 b	152 ab	825	245	17.2	2.85 ab	0.18 a
Food Waste Vermicompost – ¼ X	6.45 a	27.3 b	148 ab	895	257	16.6	2.79 ab	0.16 bc
Paper Waste Vermicompost – 1 X	6.20 ab	34.3 b	159 ab	800	246	23.4	2.96 ab	0.167 abc
Paper Waste Vermicompost – ½ X	6.15 ab	40.0 b	163 ab	880	264	18.6	3.09 a	0.18 ab
Paper Waste Vermicompost – ¼ X	6.18 ab	32.5 b	172 a	798	241	23.9	2.78 ab	0.17 ab
LSD (0.05)	0.30	20.8	32	118	27	16.6	0.33	0.02

[z] Means followed by the same letter are not significantly different at the 0.05 level, LSD

[y] LTI – Lime Test Index

Table 4. Vermicompost Raspberries: pH, Available Nutrients, Organic Matter, and Total Soil Nitrogen, 6-12 inches, Piketon, 1999.								
Treatment[z]	pH	Bray P	Exch. K	Exch. Ca	Exch. Mg	NO_3N	Organic Matter	Total Nitrogen
		----------ppm----------					%	%
Inorganic Fertilizer Control	6.38	17.3 ab	107	760	236	6.73	2.65	0.14 b
Biosolids Compost – 1X	6.38	17.5 ab	103	775	237	6.83	2.60	0.16 ab
Food Waste Vermicompost – 1X	6.25	15.8 ab	101	750	229	8.53	2.61	0.14 b
Food Waste Vermicompost – ½ X	6.23	13.5 b	92	760	228	8.23	2.61	0.16 ab
Food Waste Vermicompost – ¼ X	6.48	16.0 ab	106	835	247	8.05	2.79	0.16 ab
Paper Waste Vermicompost – 1 X	6.30	17.5 ab	109	763	238	8.30	2.78	0.17 a
Paper Waste Vermicompost – ½ X	6.35	19.3 a	111	810	254	7.75	2.78	0.17 a
Paper Waste Vermicompost – ¼ X	6.28	16.0 ab	109	760	235	7.70	2.48	0.17 a
LSD (0.05)	0.34	4.7	19	117	28	3.46	.33	0.02

[z] Means followed by the same letter are not significantly different at the 0.05 level, LSD
[y] LTI – Lime Test Index

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Table 5. Vermicompost Raspberries: Soil Analysis, Major Elements, Total Extractable, 0-6 inches, Piketon, 1999.

Treatment[z]	Al	B	Ca	Cu	Fe	K	Mg	Mn	Mo	Na	P	S	Zn
	ppm												
Inorganic Fertilizer Control	25000 ab	11.0 b	1320	9.5 b	22000 a	3310 b	1780 b	1480	1.05	211 ab	520 b	215 b	55.8 b
Biosolids Compost – 1X	25000 ab	12.2 ab	1440	10.8 a	22800 a	3310 b	1800 b	1450	1.28	210 ab	632 a	261 ab	65.5 a
Food Waste Vermicompost – 1X	25600 ab	13.7 ab	1430	10.4 ab	22600 ab	3440 b	1810 b	1540	1.53	230 ab	558 ab	253 ab	60.9 ab
Food Waste Vermicompost – ½ X	24500 a	14.1 ab	1380	9.8 ab	21800 a	3180 b	1740 b	1680	1.53	207 ab	518 b	277 a	55.7 b
Food Waste Vermicompost – ¼ X	25300 ab	11.5 b	1480	9.4 b	22700 a	3280 b	1820 b	1740	1.40	213 ab	540 ab	217 ab	56.1 b
Paper Waste Vermicompost – 1 X	25100 ab	12.9 b	1360	10.2 ab	22800 a	3280 b	1840 ab	1780	1.58	203 b	550 ab	235 ab	57.6 b
Paper Waste Vermicompost – ½ X	27500 b	15.1 a	1520	10.7 a	24000 a	3700 a	1990 a	1520	1.35	237 a	596 ab	260 ab	58.7 b
Paper Waste Vermicompost – ¼ X	25500 ab	12.3 ab	1340	10.1 ab	23400 a	3320 b	1800 b	1610	1.08	212 a	568 ab	228 ab	57.7 b
LSD (0.05)	2000	3.4	220	1.1	3400	340	150	430	0.62	35	97	61	6.3

[z] Means followed by the same letter are not significantly different at the 0.05 level, LSD

Table 6. Content of Selected Non-Nutrient Elements in Vermicomposts and Composts Applied to Black Raspberries, Piketon 1999-2000.

Amendment Type	Arsenic	Cadmium	Chromium	Cobalt	Lead	Nickel	Selenium	Strontium
	ppm							
Food Waste Vermicompost	<2.7	1.5	11.9	23.1	113.9	14.3	<6.0	229.8
Paper Waste Vermicompost	<2.7	1.4	8.4	51.5	18.1	38.5	9.9	101.9
Biosolids Compost	<2.7	2.7	3.7	27.7	40.5	19.4	<6.0	65.2
Yard Waste Compost [z]	<2.7	0.5	7.2	2.2	19.3	4.4	<6.0	82.8

[z] Replaced Food Waste Vermicompost for the spring, 2000 surface application.

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